Neutronics, Shielding, and Activation Analyses for the Li_2O Particulate Concept

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VV and Magnet Shielding

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- For reweldability, the peak helium production in the VV should not exceed 1 appm
- Adequate VV shielding is provided using
  35 cm SS/H_2O reflector/shield behind 70 cm OB blanket
  50 cm SS/H_2O reflector/shield behind 40 cm OB blanket
- End-of-life insulator dose in superconducting magnet should not exceed 10^9 Rads
- Adequate magnet shielding is provided by
  75 cm SS/H_2O shield/VV behind 70 cm OB blanket
  90 cm SS/H_2O shield/VV behind 40 cm OB blanket

VV and Magnet Shielding (Continued)

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- Magnet radiation effects:
  End-of-life insulator dose 10^9 Rads
  End-of-life fast neutron fluence 5×10^{17} n/cm^2
  End-of-life Cu stabilizer damage 3.2×10^{-4} dpa
  Peak power density 0.16 mW/cm^3

- Preliminary radial build that satisfies requirements for SS structure lifetime, VV reweldability, and superconductor shielding is

  Outboard: 145 cm total
  70 cm Blanket, 35 cm reflector/shield, 40 cm VV/shield
  Inboard: 130 cm total
  40 cm Blanket, 50 cm reflector/shield, 40 cm VV/shield

Preliminary Activation Results

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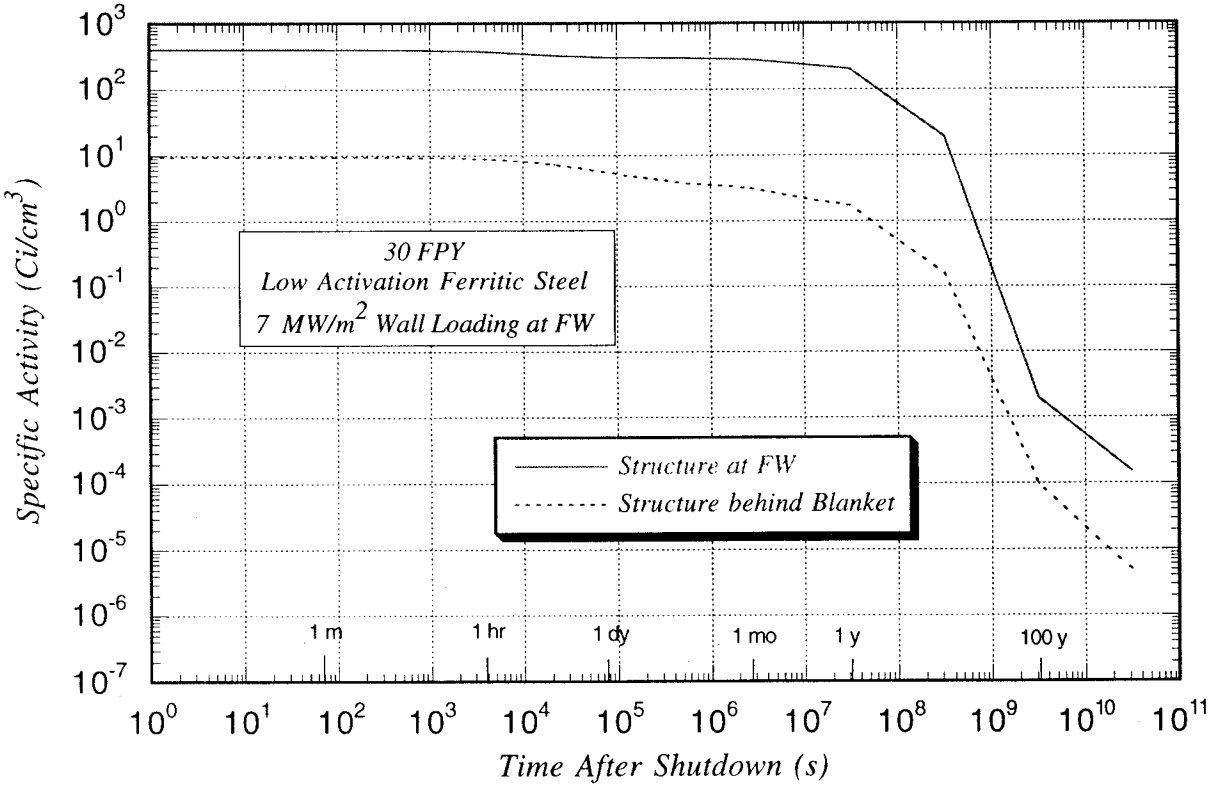
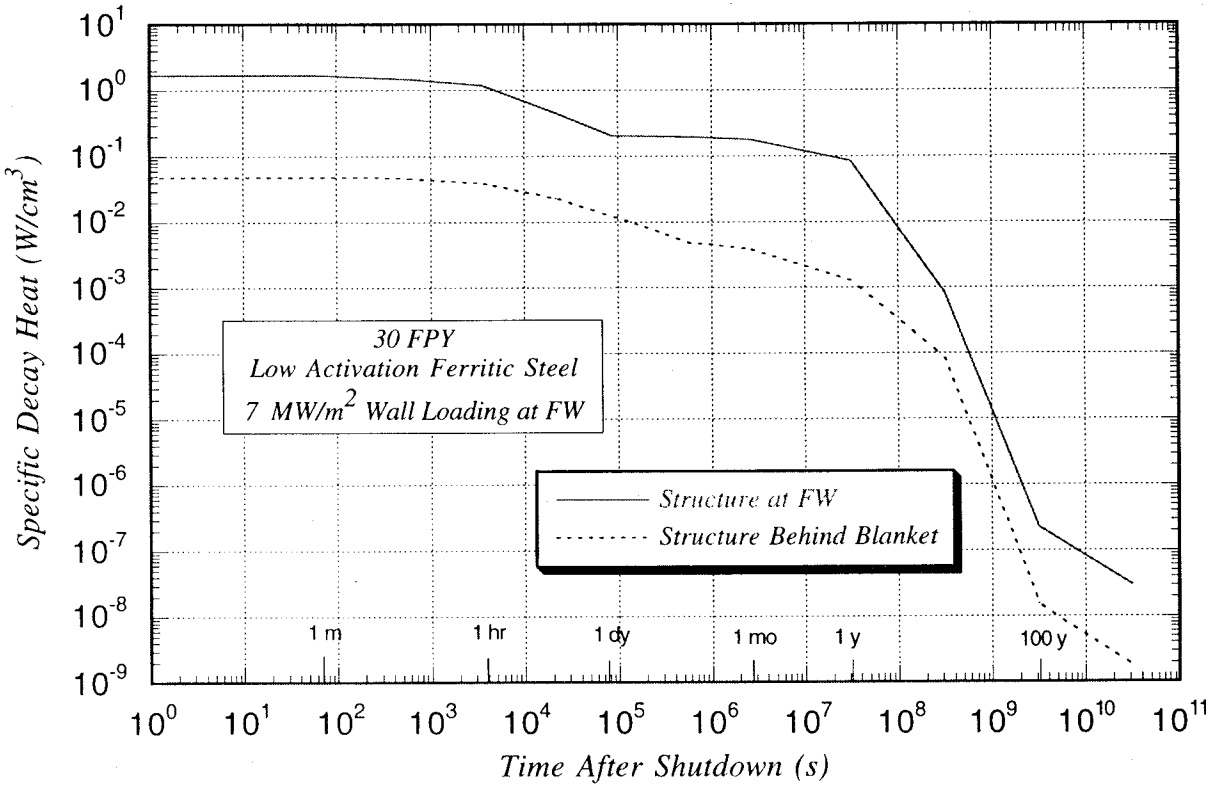
- Preliminary activation calculations performed for 316SS structure with 7 MW/m^2 neutron wall loading at the FW
- The impact of using low activation ferritic steel (ORNL LAFS 9Cr-2WVTa) was considered
- The short term structure radioactivity affecting decay heat and off-site dose from accidental release is reduced significantly due to attenuation in the blanket
- Peak specific activity in LAFS behind the 70 cm blanket is 9.5 Ci/cm^3 at shutdown compared to 408 Ci/cm^3 if the structure is at the FW
- Peak specific decay heat in LAFS behind the 70 cm blanket is 0.048 W/cm^3 at shutdown compared to 1.73 W/cm^3 if the structure is at the FW

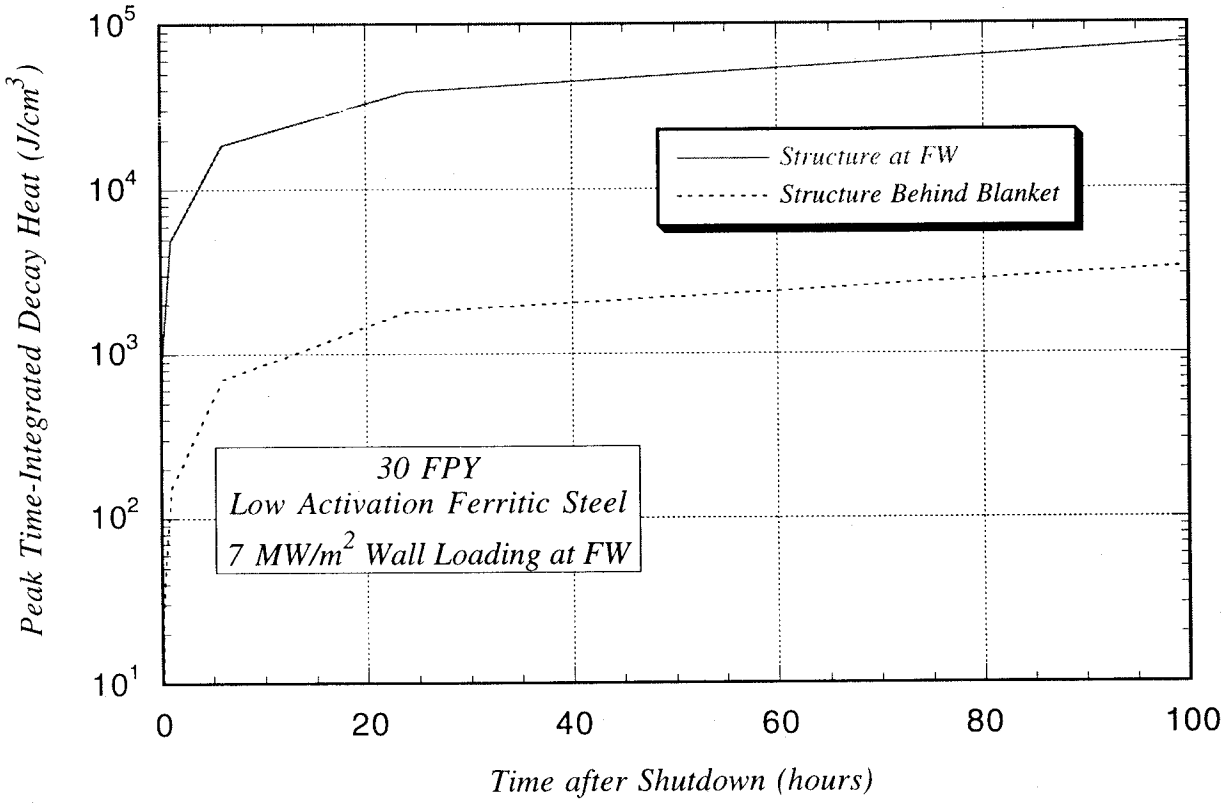
Structure Activity Reduced by More Than an Order of Magnitude in the Li_2O Particulate Concept



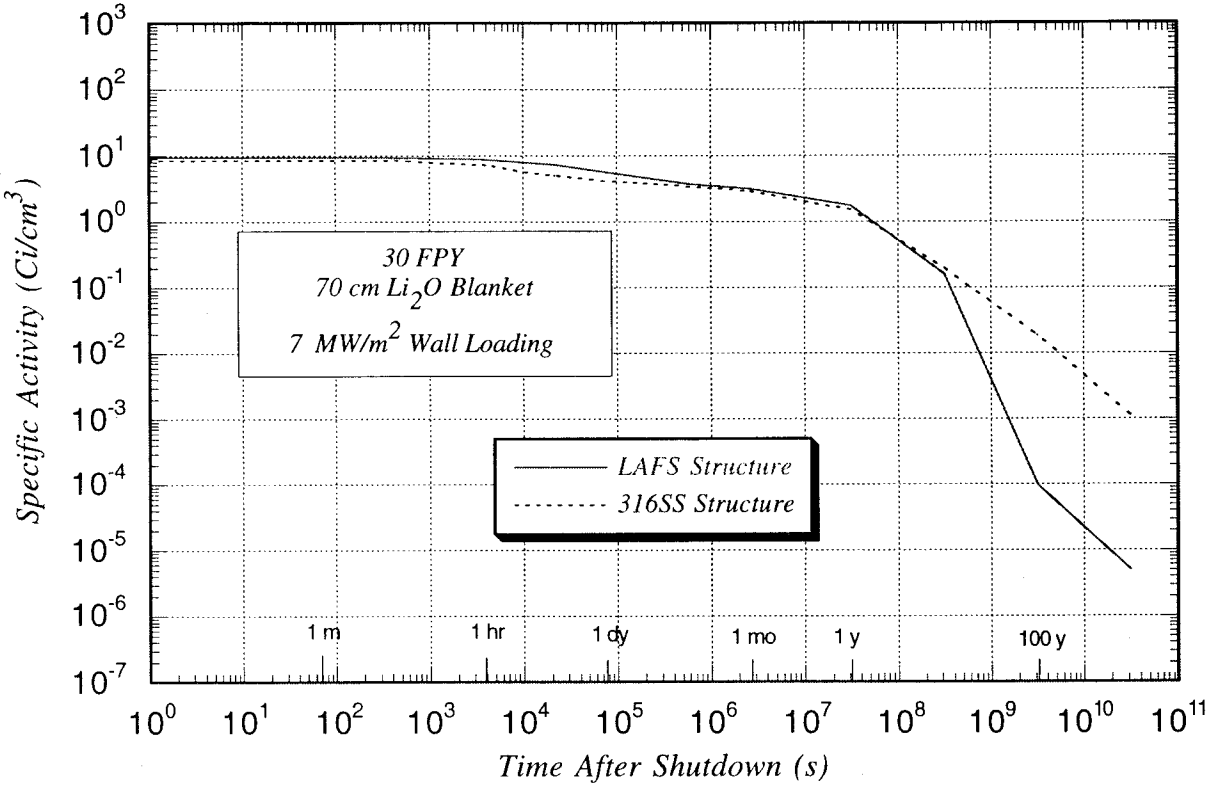
Structure Decay Heat Reduced by More Than an Order of Magnitude in the Li_2O Particulate Concept



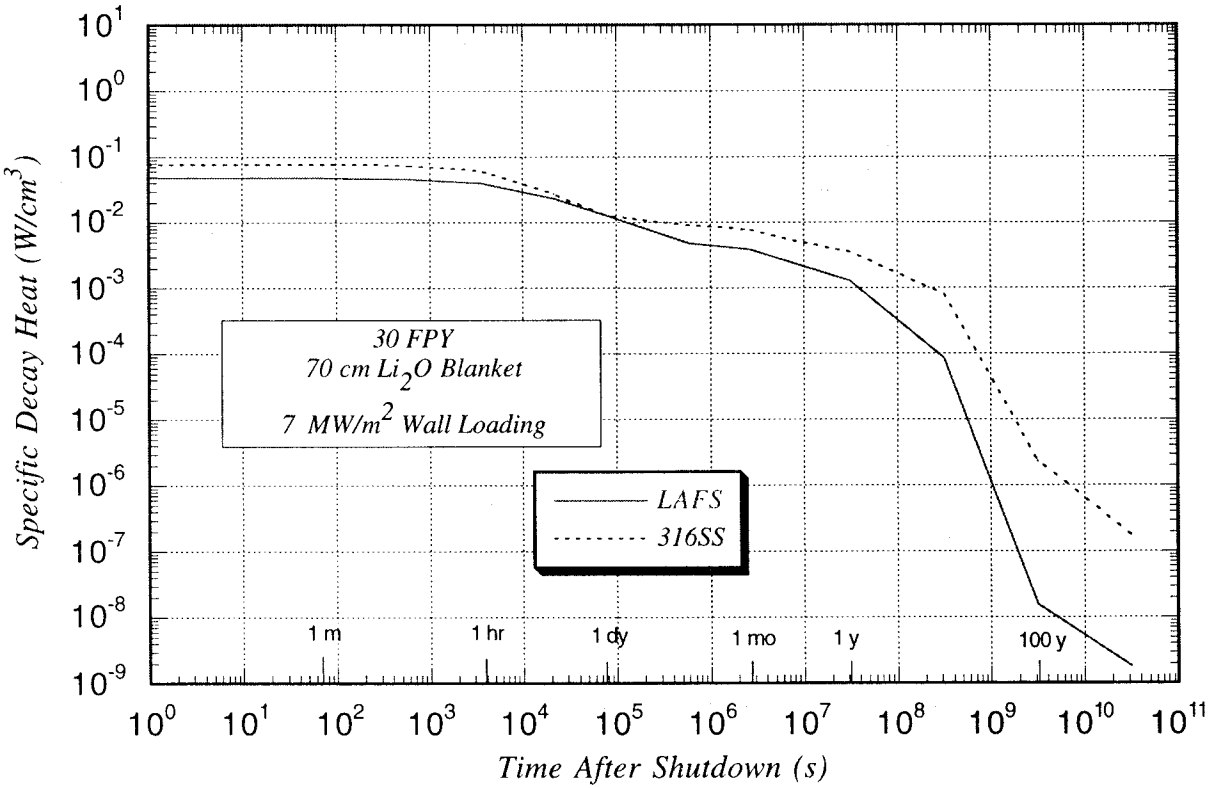
Time-Integrated Decay Heat in Structure Drops by More Than an Order of Magnitude behind Li_2O Particulate Blanket



Long Term Structure Activity Reduced by More Than Two Orders of Magnitude for Low Activation FS compared to 316SS



Structure Decay Heat is Lower for Low Activation Ferritic Steel Compared to 316SS



Preliminary Radwaste Assessment

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- WDR for 316SS in the reflector/VV/shield is 1.93 (WDR is contributed mostly by the 20 wppm Nb impurity in 316SS)
- Reduction in long term activity (fluence dependent) not as significant as in short term activity (flux dependent) since the structure is used for the whole reactor life (30 FPY) while in conventional designs, the FW/blanket structure is replaced after ~ 2 FPY
- Class C radwaste classification for near surface burial can be achieved by using low activation structure with reduced Nb content
- When the low activation ferritic steel (9Cr-2WVTa with 0.5 wppm Nb) was used instead of 316SS, the WDR is reduced allowing for near surface burial

	Front 0.5 cm of structure	90 cm thick reflector/VV/shield
316SS	20	2
LAFS	0.3	0.025

Summary

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- Overall TBR>1.2 is achievable
- A minimum blanket thickness of 40 cm required for structure to be lifetime component
- A total blanket/reflector/shield thickness of 105 cm required to allow for VV rewelding
- An additional 40 cm thick VV/shield required for adequate magnet shielding
- More than an order of magnitude reduction in decay heat and short term activity results from placing the structure behind the Li_2O particulate blanket
- Using LAFS permanent structure behind the Li_2O particulate blanket allows for near surface burial of the radwaste

Preliminary Nuclear Analysis for the Li_2O Particulate Concept

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- 5 cm front blanket layer of Li_2O @30% packing fraction
- 0.5 cm SiC baffle
- Li_2O blanket @60% packing fraction
- Reflector/VV/shield consisting of 80% 316SS and 20% H_2O
- 7 MW/m^2 neutron wall loading at the FW
- 1-D calculations for local nuclear parameters

Preliminary Nuclear Analysis for the Li_2O Particulate Concept (Continued)

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- Effect of blanket thickness and Li enrichment on TBR, M, and SS damage investigated
- Overall TBR and M estimated for tokamaks with different aspect ratios
- Shielding requirement for the VV and superconducting magnet determined
- Impact on activation, decay heat, and waste disposal assessed

TBR Increases Reaching a Maximum Value of 1.3 and M Decreases Slightly with Thickness Increase

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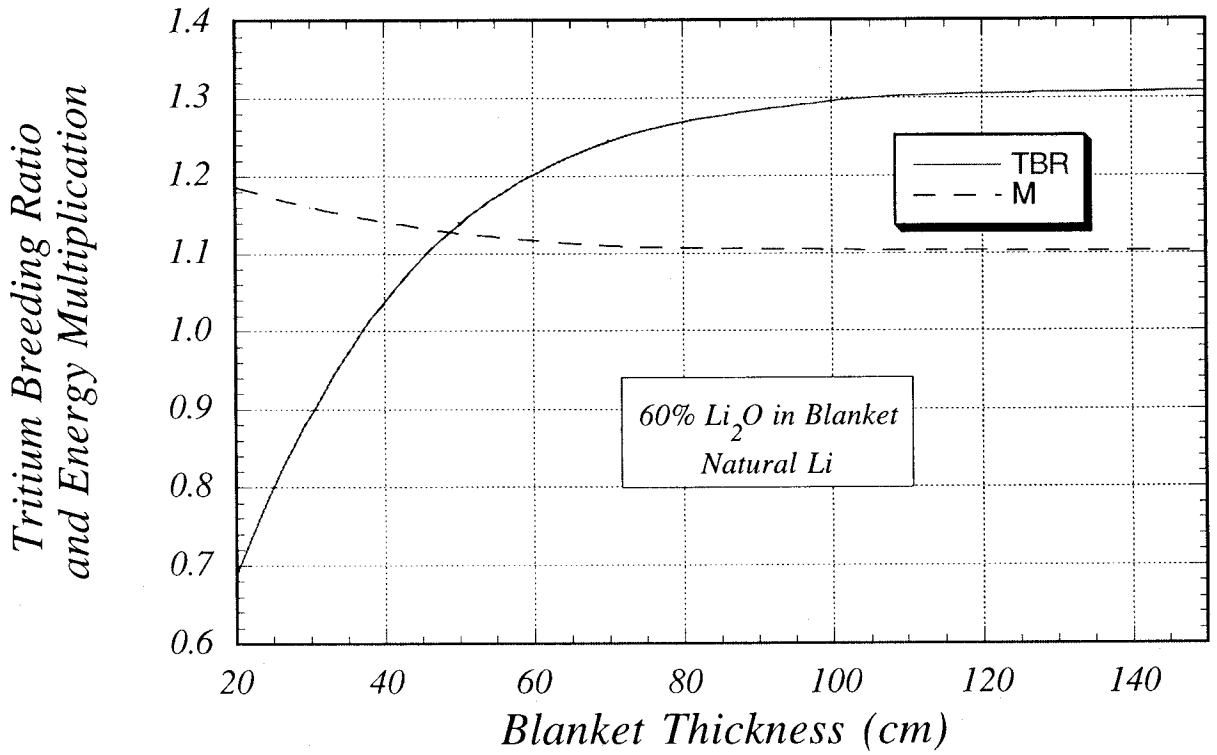

SS Damage and Gas Production Decrease by an Order of Magnitude for Each Additional 35 cm Blanket Thickness

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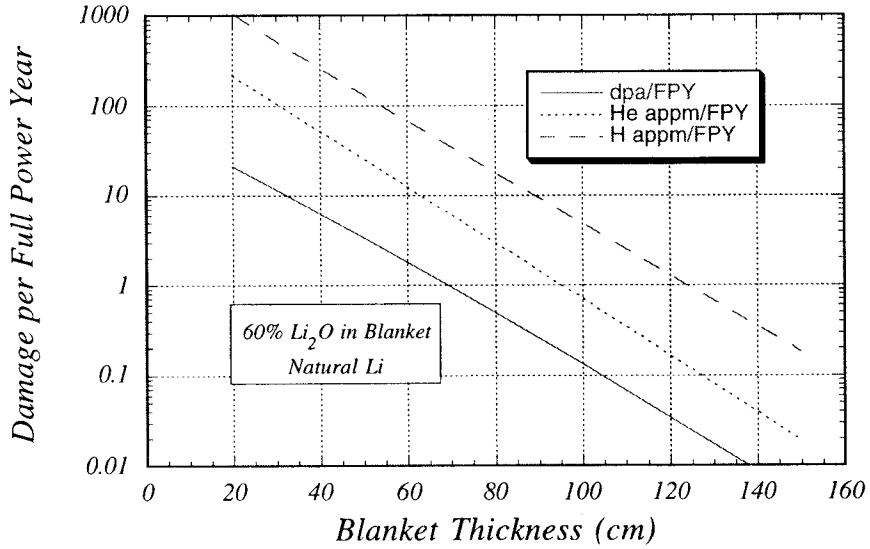

- A minimum blanket (Li_2O @ 60%) thickness of 40 cm is required for the SS structure to be lifetime component (200 dpa @ 30 FPY)
- A minimum blanket (Li_2O @ 60%) thickness of 145 cm is required in front of the SS VV to be reweldable (1 He appm @ 30 FPY)

Enriching the Li Results in Significant Decrease in TBR and Negligible Increase (<1%) in M

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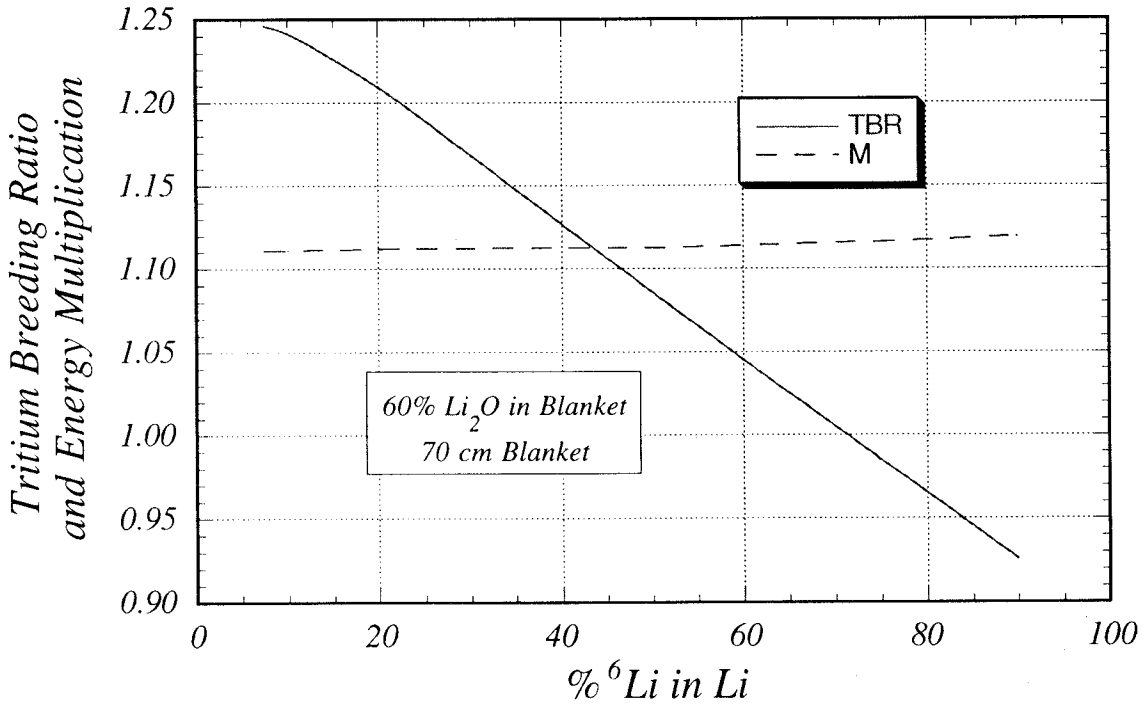

Preliminary Neutronics Parameters

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- Natural Li
- Total blanket thickness:
  - Outboard 70 cm (for breeding)
  - Inboard 40 cm (for structure shielding)
- Local TBR:
  - Outboard 1.246
  - Inboard 1.044
- Local M:
  - Outboard 1.11 (4.3% in reflector/VV/shield $\Rightarrow$ cold shield)
  - Inboard 1.14 (17.6% in reflector/VV/shield)

Radiation Damage

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- SiC baffle (not structure member) will require replacement
  61 dpa/FPY
  6683 He appm/FPY
  4629 H appm/FPY
  Lifetime criterion for non-structural material not defined

- SS structure at back of blanket is lifetime component

  Outboard: 0.95 dpa/FPY $\Rightarrow$ 29 dpa @ end-of-life
  6.15 He appm/FPY
  34.7 H appm/FPY

  Inboard: 6.26 dpa/FPY $\Rightarrow$ 188 dpa @ end-of-life
  52.2 He appm/FPY
  260 H appm/FPY

Preliminary Estimate of Overall TBR

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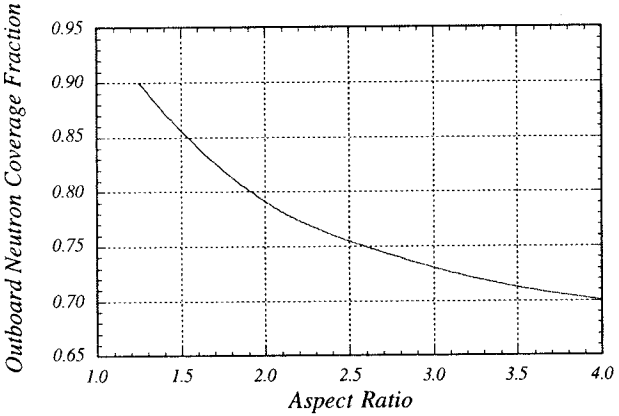
- Overall TBR depends on neutron coverage fraction of the regions surrounding the plasma and blanket thickness in each region



- NCF depends on aspect ratio

- Low Aspect Ratio (ARIES-ST A= 1.6)
  84% OB, 9% IB, 7% div ⇒ 1.21 overall TBR

- High Aspect Ratio (ARIES-IV A= 4)
  70% OB, 20% IB, 10% div ⇒ 1.19 overall TBR

- Penetrations for heating and current drive cover <1% of FW area in conceptual fusion designs and have negligible impact on overall TBR